

# The influence of sludge retention time on sludge flocculation in IFAS system

Mengdi Wang<sup>1,a</sup>, Yue Wen<sup>1,b</sup>

<sup>1</sup> State Key Laboratory of Pollution Control and Resource Reuse, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, PR China

<sup>a</sup> wmd0213@tongji.edu.cn, <sup>b</sup> ywen@tongji.edu.cn

**Abstract.** The IFAS system was cultivated in five sequencing batch reactors. The sludge retention times (SRT) were 6 d, 8 d, 10 d, 15 d and 25 d respectively. In this dissertation, the influence of SRT on suspended sludge flocculation in IFAS system and its mechanisms were studied. It was found that in the IFAS system, the specific turbidity of supernatant and SVI value of suspended sludge both decreased as the SRT increased. In addition, extending SRT was capable of reducing the extracellular polymeric substances (EPS) content and the interaction energy barriers, increasing the percentage of bivalent and trivalent cations in pellet, thus improved the sludge flocculation and reduced effluent turbidity.

## 1. Introduction

Integrated Fixed-film Activated Sludge (IFAS) is a modified process of activated sludge (AS) which, by adding a fixed media to a suspended growth pond, causes to increase microbial population and enhance degradation speed of organic compounds [1]. Nowadays, IFAS is gaining increasing acceptance as an option for upgrading activated sludge plants to advanced nutrient control in many facilities.

In IFAS system, the sludge flocculability is essential for the solid/liquid separation. Poor sludge flocculability leads to an increase in the effluent turbidity. It has been reported that, attached growth in IFAS system tends to be a lower SVI value [2]. The increasing of SRT could enhance AS flocculation. Moreover, EPS bridging theory, Derjaguin–Landau–Verwey–Overbeek (DLVO) theory and multivalent bridging theory, and steric interactions are often used to interpret colloid stability and to describe the microorganisms and AS flocculation [3]. The aforementioned studies indicated that SRT, total interaction energy, EPS content, multivalent cations all correlate with the AS flocculation.

In this study, the influence of SRT on sludge flocculation in IFAS system and its mechanism were studied from the angle of DLVO total interaction energy, EPS content and distribution of multivalent cations in AS.

## 2. Materials and Methods

### 2.1. IFAS configuration and operation

The IFAS system was cultivated in five sequencing batch reactors, with a useful volume of 10 L. The SRT were 6 d, 8 d, 10 d, 15 d and 25 d respectively. Each reactor was seeded 5 L AS from Qu Yang WWTP (in Shanghai, China). All the reactors were filled with 30% ( $V_{\text{support}}/V_{\text{reactor}}$ ) K1 media, whose specific surface area for biofilm growth is 500 m<sup>2</sup>/m<sup>3</sup> of reactor. The cycle time was 12 h, and the cycle profile comprised the following phases: 12 min feeding, 677 min aeration, 30 min sedimentation



and 12 min withdraw. The dissolved oxygen concentration was around  $7.0\sim 7.5\text{ mg}\cdot\text{L}^{-1}$ ; the temperature was kept at  $22 \pm 1\text{ }^{\circ}\text{C}$ , and pH was maintained between 7 and 8 in all reactors.

## 2.2. Analytical techniques

The AS was collected for the experiments on the condition that the fluctuation of these parameters such as the COD, turbidity and SVI in the effluent was less than 20%. All the AS samples were wasted during the last 10 min of the aeration phase.

According to an ultrasonic concussion extraction method, the AS samples were separated into four parts: bulk solution, LB-EPS, TB-EPS, and pellet. The EPS content was defined as the sum of carbohydrates, proteins, and humic substances [4]. The AS interaction energy curves were determined by a contact angle approach. The cation concentrations in the bulk solution, LB-EPS, TB-EPS, and pellet were analyzed by inductively coupled plasma optical emission spectrometry.

## 3. Results and discussion

### 3.1. The influence of SRT on the flocculation-related characteristics

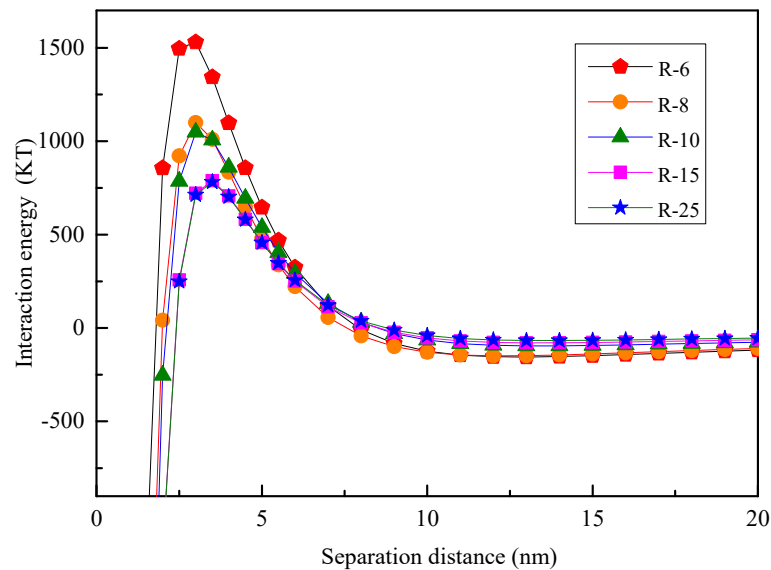
The influence of SRT on the flocculation-related characteristics of AS are listed in Table 1. The specific turbidity and SVI value both decreased as the SRT increased. Compared to the SRT of 6 d, the specific turbidity reduced 75.8% with the SRT of 15 d, but all the VSS/SS values were around 0.80. However, the extent of SVI reduction was relatively small, and the SVI was only reduced 7% with SRT of 15 d in comparison with that of 6 d.

**Table 1.** The influence of SRT on the flocculation-related characteristics of AS

	MLSS ( $\text{mg}\cdot\text{L}^{-1}$ )	VSS/SS	Zeta potential (mV)	contact angle ( $^{\circ}$ )	specific turbidity ( $\text{NTU}/\text{g SS}$ )	SVI ( $\text{mg}\cdot\text{L}^{-1}$ )
R-6	1202 $\pm$ 59	0.81 $\pm$ 0.05	-21.7 $\pm$ 1.1	15.35 $\pm$ 1.63	6.28 $\pm$ 0.78	87 $\pm$ 6
R-8	1728 $\pm$ 43	0.79 $\pm$ 0.04	-19.7 $\pm$ 1.5	19.75 $\pm$ 1.76	4.48 $\pm$ 0.21	84 $\pm$ 2
R-10	2014 $\pm$ 75	0.83 $\pm$ 0.03	-18.4 $\pm$ 1.3	20.28 $\pm$ 2.22	3.57 $\pm$ 0.48	83 $\pm$ 4
R-15	2434 $\pm$ 115	0.80 $\pm$ 0.02	-17.1 $\pm$ 1.5	24.55 $\pm$ 0.44	3.06 $\pm$ 0.40	81 $\pm$ 10
R-25	2982 $\pm$ 209	0.79 $\pm$ 0.05	-16.9 $\pm$ 0.8	25.42 $\pm$ 1.81	1.52 $\pm$ 0.16	81 $\pm$ 3

### 3.2. The influence of total interaction energy on AS flocculation

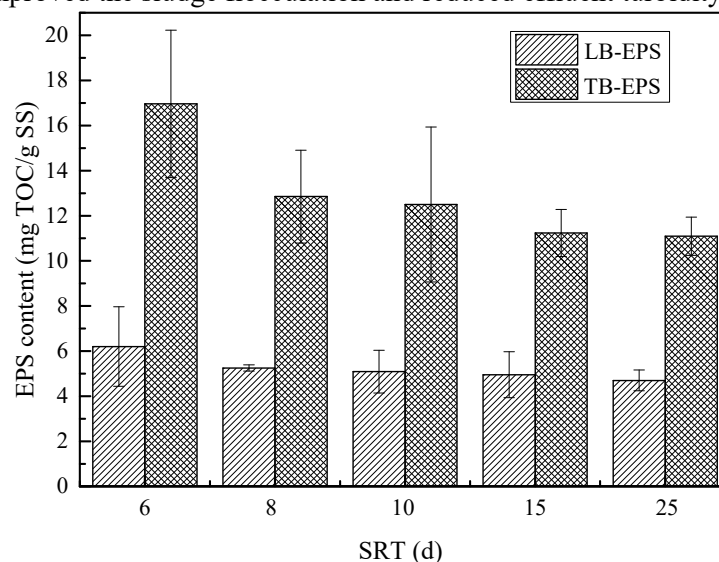
The total interaction energy curves of AS with different SRT is shown in Figure 1. The interaction energy barriers increased as the SRT decreased, and the reduction scale was not uniform. Compared to the scenario with SRT of 6 d, the barrier reduced 49% when the SRT was 15 d. The barriers of DLVO energy was positively correlated with supernatant turbidity. The above results demonstrated that multivalent cations are capable of reducing the interaction energy of sludge surface and compressing the double electrical layers through neutralization [5].



**Figure 1.** The total interaction energy curves of AS with different SRT

### 3.3. The influence of LB-EPS and TB-EPS content on AS flocculation

The LB-EPS and TB-EPS content in AS with different SRT is shown in Figure 2. As the SRT increased from 6 d to 25 d, the LB-EPS and TB-EPS contents both decreased, but the TB-EPS content was always higher than the LB-EPS content. Besides, both LB-EPS and TB-EPS content declined and positively correlated with specific turbidity, and the former correlation was higher than the later one. It indicated that extending SRT was capable of compacting the sludge aggregates through reducing the EPS content, thus improved the sludge flocculation and reduced effluent turbidity.



**Figure 2.** The LB-EPS and TB-EPS content in AS with different SRT

### 3.4. The influence of multivalent cations on AS flocculation

The bivalent cations ( $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ) were existed in the bulk solution. When the SRT extended, the percentage of bivalent cations in bulk solution gradually decreased, while the percentage in the pellet increased. The trivalent cations ( $\text{Al}^{3+}$  and  $\text{Fe}^{3+}$ ) could be only detected in the pellet, and the trivalent cations content in the pellet was gained as the SRT increased. The multivalent cations could improve the sludge flocculation performance through the following pathways: on the one hand, they could

reduce the surface interaction energy via charge neutralization; on the other hand, they could bind with sludge closely and reduce the EPS content [6].

#### 4. Conclusion

In IFAS system, the LB-EPS and TB-EPS content were both positively correlated with the SVI value. Long SRT allows the multivalent cations having longer time to interact with the new productive amount of sludge. It is not only aggregating the small flocs into larger flocs through bridging function, but also reconstructing the sludge structure, squeezing the water out of the flocs and compacting the sludge aggregates. Therefore, the sludge flocculation performance got enhanced.

#### Acknowledgments

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